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A Critique and Extension of a Model of Technology Transfer

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1. Introduction

For developing countries to narrow the productivity and income gap with developed countries, they must acquire new technology. Through what channels does technology diffuse most consistently and rapidly? A widely held view seems to be that FDI is among the most effective channels of technology transfer, yet empirical evidence to support this view is mixed. Harrison (1996) summarizes the results of several studies, based on recently available firm-level data for three developing countries, which found that little or no technological spillover occurred from FDI to local firms in the same sector. In one of these studies, Aitken and Harrison (1999) even found negative spillovers to locally owned firms in the same sector. Harrison (1996) speculated that one cause might be that multinationals were able to recruit and retain the best skilled workers, leaving local firms with reduced capacity to learn new technology.[1] Indeed, in view of abundant empirical evidence that multinational subsidiaries in developing countries pay a wage premium to skilled workers compared to locally owned firms there, it might be surprising that these local firms are ever able to recruit skilled workers away from multinationals.

The purpose of this paper is explore two modifications of a recent model of technology transfer. The model, by Glass and Saggi (1999), is appealingly simple and succeeds in capturing some aspects of technology transfer through movement of trained workers among firms. However, in achieving simplicity it does sacrifice some realism, and especially features of these interactions which might generate outcomes, including wage

[1] Aitken and Harrison (1999) suggest that if firms have scale economies and if the multinational takes some of the local firm's market share, this could also explain the decline in local firms' productivity.

predictions, that correspond better to observed facts. In this paper I modify the model to incorporate some more realistic features, in the search for a model whose outcomes somewhat better fit the data. The two key facts I seek to explain are (1) that FDI does not always lead to technology transfer and (2) that skilled workers receive a wage differential relative to unskilled workers and the average wage differential in multinational firms exceeds that in locally owned firms. While the models explored turn out not to yield much improvement in explaining these facts, the results point the way to additional modifications which may be more successful in doing so, and these are explored in a companion paper (Larudee 2000).

The specific channel of technology transfer examined here is training of skilled workers in multinationals followed by their movement to local firms. However, the explanation will not be that multinationals recruit workers of higher native ability. Instead, throughout this paper I will assume that before workers receive training in the multinational they all have the same level of ability. Thus the differentiation of workers with respect to skill level, productivity and wages will result entirely from differences in how much training they receive.

To explore these issues, section 2 summarizes the Glass-Saggi model and explains how wages are determined in it, and then discusses possible alterations in assumptions which would generate different wage predictions and therefore a different amount of technology transfer. Section 3 extends the model to two periods, showing how intertemporal considerations change the outcomes and predicted wages. Section 4 sketches outcomes in the model with more than 2 periods, and section 5 concludes.

2. The Glass-Saggi model with modified wage determination

Glass and Saggi (1999) model technology transfer through FDI to locally owned firms in developing countries as a static Cournot duopoly, with one multinational subsidiary ("the source firm") and one locally owned firm ("the host firm"). The two firms play a three-stage game, competing to hire workers and then producing a homogeneous good for an export market. The multinational always uses an advanced technology, while the host firm either produces using a backward technology and untrained workers, or else successfully hires trained workers away from the multinational by offering them a wage which the multinational does not find it optimal to match. From an infinitely elastic local labor supply, whose only alternative employment pays a reservation wage of $w = 1$, a worker can be hired into the multinational, instantly and costlessly learn the advanced technology, and instantly become available to be hired into the host firm to operate the advanced technology. However, technology is transferred imperfectly: in the host firm all the former multinational workers use q units of labor ($q > 1$) to produce a unit of output which in the source firm would have taken them only 1 unit of labor to produce. The host firm's alternative, to employ untrained workers, is assumed always worse: they use Q labor units per unit of output, with $Q > q$.

In stage one of the game, the source firm makes a wage offer to workers. In stage two the host firm makes a wage offer, and if it is higher workers are recruited to the host firm so that technology transfer occurs; otherwise they remain in the source firm and no technology transfer takes place. In stage three the firms interact as a Cournot duopoly, choosing output and determining price and profits. Each party has complete information about the decisions of its rival, and the game is solved by backward induction.

Technology transfer takes place whenever the host firm is willing to pay a higher wage to recruit trained workers than the multinational is willing to pay to retain them. Suppose in stage 1 the source firm knows that its own maximal wage offer to retain its workers (W_S) is higher than will be the maximal wage offer of the host firm to try to recruit them (W_H). The source firm will pay the host firm's highest offer (plus an arbitrarily small e); the host firm will pay the reservation wage, assumed equal to unity, and hire from the general labor pool. In this case, workers once trained will remain in the source firm, and no technology transfer will occur.

Now suppose instead that in stage 1 the source firm knows that in stage 2 the host firm is prepared to match and exceed its highest wage offer. The source firm will then surrender the field and pay only the reservation wage $w = 1$, letting the first group of workers take their training and run to the host firm, and hiring another group of trainees from the general labor pool. In this case, technology transfer will occur. Note that a wage offer that a firm is hypothetically willing to make is denoted here by W, while a wage that it actually ends up paying is denoted by w.

Glass and Saggi (1999) show that, if there is any range of q values at all for which the source firm finds it optimal to prevent technology transfer, it must be for relatively large values of q, close to Q. In this range, the host firm enjoys only a small productivity gain by recruiting trained workers from the source firm, and so is only willing to offer a small wage premium to recruit them. Thus in this range the source firm is willing to make a larger wage offer, and technology transfer fails to occur. For example, they show that for linear demand, if $Q > 2$, then technology transfer fails to take place when $q \in [2,Q]$.

Notice that the host firm in the end always pays the reservation wage no matter whether technology transfer occurs or not. (Actually, in case technology transfer occurs, it pays the reservation wage plus *e*, but *e* is arbitrarily small.) Thus the decision by the host firm that it is (or is not) willing to match a given source firm wage offer refers to a purely hypothetical situation; the maximal wage W_H that the host firm is willing to match is not a wage that the host firm ever actually pays in practice. However, it *is* a wage w_S that the *source* firm pays in practice in the case that no technology transfer occurs.

This outcome is an artifact of the wage determination process postulated by Glass and Saggi. Let us look at the process from the standpoint of the host firm. GS argue that the host firm will choose its wage offer by maximizing profit as follows: for each possible source firm wage offer W, the host firm will be willing to match that offer and hire trained workers if and only if doing so lowers its own marginal cost below the marginal cost Q of employing untrained workers. Thus when $W < Q/q$ the host firm is willing to match the source firm's offer, and technology transfer will occur unless the source firm is willing to pay Q/q or more. In effect, writing profit as a function of the source and host firm marginal costs as $p_H(c_S,c_H)$, the host firm compares $p_H(1,Wq)$ with $p_H(1,Q)$. If the former is larger the host firm is willing to match wage W; if not it will yield, pay only the reservation wage and employ untrained workers. Denoting by W_H the highest wage the host firm is willing to match, $W_H = Q/q$.

The source firm then compares two options: in the first, it chooses to pay W_H and retain its workers, so that its profit is $p_S(W_H,Q)$ or equivalently $p_S(Q/q,Q)$, and in the second it lets them go, so that its profit is $p_S(1,q)$. Both profit functions are increasing in q, but when technology is highly transferable to the host firm (values of q close to 1) it is more profitable for the source firm to let technology transfer occur, and when technology is poorly transferable (values of q close to Q) it is more profitable for the source firm to prevent technology transfer. More precisely, GS show that if there is any interval of q for which technology transfer fails to occur, it must be in the high end of the interval $[1,Q]$. For linear market demand, they show that $q = 2$ is the lowest value of q at which the source firm chooses to pay Q/q and prevent technology transfer.

This outcome, however, hinges crucially on the assumption that the wage bidding is a sequence of two moves, first by the source firm and second and last by the host firm. If the source firm were permitted to make a counteroffer after the host firm's bid, the host firm could not succeed in recruiting trained workers by paying just above the reservation wage. Instead, the host firm would have to pay just above the source firm's maximal wage offer in order to recruit these workers. If a counteroffer is allowed, then the outcome entirely changes. Now the host firm, given a source firm wage offer W, does not compare $p_H(1,Wq)$ with $p_H(1,Q)$ but instead compares $p_H(1,Wq)$ with $p_H(W,Q)$, and decides to be willing to match W if the former profit is larger. Then W_H, its maximal wage offer, occurs when

$$p_H(1,W_H q) = p_H(W_H,Q) \tag{1}$$

The source firm follows a similar procedure, choosing its maximal wage offer where

$$p_S(1,W_S q) = p_S(W_S,Q) \tag{2}$$

For all q for which $W_S > W_H$, the source firm retains its workers and technology transfer is prevented. At the boundary between values of q at which technology transfer occurs and those at which it fails to occur, $W_S = W_H$. Thus in order to find q_S, the switchpoint, we need only solve equations (1) and (2) simultaneously, setting the two wages equal.

For linear demand ($P = a - b(Q_H + Q_S)$, where Q_H and Q_S are total output of the host and source firm respectively) the only value of W ($= W_S = W_H$) which satisfies both equations is $W = 1$. This is because a given host firm isoprofit curve drawn in (c_S,c_H) space (a straight line with slope 1/2) intersects any given source firm isoprofit curve (a straight line with slope 2) only once, so that if two points are both on both firms' isoprofit curves, the two points must coincide. If $W = 1$, this is indeed the case, and we also must have $q = Q$. Thus the addition of a source firm counteroffer to the game eliminates any switchpoint inside the interval $q \in [1,Q]$. Does this mean that technology transfer always occurs, or never occurs? As Glass and Saggi show, for $q = 1$ it is more profitable for the source firm to pay the reservation wage and let technology transfer occur. Thus allowing a source firm counteroffer means that technology transfer always occurs.

Allowing a counteroffer certainly seems to be a more realistic specification, so it is a bit unsettling that it leaves us without an explanation for the fact that technology transfer sometimes fails to occur. Furthermore, by itself – without any other changes in the model – it generates wage predictions that are in one respect even farther from observed facts than the GS model's predictions. The GS model says that in case *N* occurs, the source firm pays a wage premium to skilled workers. This accords with the empirical evidence. The model also says that in case *T* occurs, all workers – skilled and unskilled – get the same pay in both firms, and this does *not* accord with the evidence (or with intuition). Allowing a counteroffer ensures that skilled workers always get paid more than unskilled workers, which accords better with observed fact and with intuition. But it also implies that under technology transfer, the host firm pays a higher wage than the source firm, which does not accord with observed facts.

The problem is that in the interest of simplicity the GS model makes assumptions which imply that the host firm either replaces its entire workforce with trained workers, or else hires no trained workers at all. But much anecdotal and historical evidence indicates that a host firm often hires one or a very few trained workers and uses them to train other skilled workers. A model which admitted this possibility would have the potential to preserve the source/host wage differential in the *average* skilled wage, and still allow the host firm to outbid the source firm for the services of a few trained workers. Constructing such a model is left to future research.

Are there other reasons why the GS model, modified by the addition of a source firm counteroffer, generates more technology transfer than is observed in practice? One might be that the GS assumption of costless and instanteous training implies that the negative consequences to the source firm of losing a trained worker are small. Making the cost of training positive, and larger for less-trained workers, would give the source firm more incentive to bid to retain trained workers. Such a model is explored in a companion paper (Larudee 2000), and it does turn out to predict that for some sets of parameter values technology transfer fails to occur.

3. Adding a newer vintage of technology

We return now to the original GS model and show that extending it to two periods, with a newer vintage of technology introduced by the source firm in the second period, increases the range of q over which technology transfer will occur in period 1.

We make these additional assumptions:

(1) Vintage 2 of technology is more productive by a factor of g than vintage 1. The source firm's labor usage per unit of output (unit labor requirement, or ULR) falls from 1 to

$1/g$. When the host firm employs a worker trained in the source firm to operate vintage 2, the ULR is q/g.

(2) An untrained worker from the general labor pool is less productive in operating vintage 2 than vintage 1, so if the host firm is stuck with untrained workers it will always assign them to operate vintage 1, with ULR Q.

In the two-period game, the structure of the game in the last period – period 2 – is exactly like that of the static game, and the solution procedure is the same. The switchpoint value of q at which the source firm begins to pay a wage premium to prevent technology transfer is also the same – namely, for linear demand, $q = 2$. What is new in the two-period game is that some of the period-1 wage decisions are influenced by intertemporal considerations. Let us denote the outcomes by two letters (*T* for technology transfer, *N* for no-technology-transfer), the first giving the period-1 outcome and the second giving the period-2 outcome. Then the four possible outcomes are *NN*, *NT*, *TN*, and *TT*. It is in the case *NN* that the wage paid by the source firm differs from what the static GS model predicts.

Suppose $q > 2$ so that everyone knows *N* will occur in period 2. Then the host firm is motivated to act strategically in period 1 to secure a more favorable structure of marginal costs under which to experience *N*. It can do this by securing *T* in period 1. Why? Because doing so allows the host firm to enter period 2 with 1-trained workers (instead of untrained workers), giving it lower marginal cost (q instead of Q) and hence higher period-2 profit.

What this means is that in this particular case – when *N* will occur in period 2 – the host firm will be willing to pay a higher wage premium in period 1 than predicted by the static game, in order to reap this extra period-2 gain. In this model the practical effect (since the host firm in practice always pays the reservation wage) is to force the source firm to pay a higher wage (denoted w_{S1}) to enforce N in period 1.

The wages and marginal costs implied by the two-period model are shown in Table 1, except that w_{S1} is derived below. A firm's marginal cost is its wage times its ULR. Recall that in vintage 1, the source firm's ULR is 1 and the host's is q. In vintage 2, these are $1/g$ and q/g respectively. Several examples will clarify the derivations.

Table 1. Wage and marginal cost in the two-period extension of the Glass-Saggi model.

	Period 1				**Period 2**			
	Wage		**Marginal cost**		**Wage**		**Marginal cost**	
	w_{S1}	w_{H1}	c_{S1}	c_{H1}	w_{S2}	w_{H2}	c_{S2}	c_{H2}
NN	w_{S1}*	1	w_{S1}*	Q	gQ/q	1	Q/q	Q
NT	Q/q	1	Q/q	Q	1	1	$1/g$	q/g
TN	1	1	1	q	g	1	1	q
TT	1	1	1	q	1	1	$1/g$	q/g

*The expression for w_{S1} is found in equation (3) below in the text.

First we look at period 1. When technology transfer occurs (TN or TT), both firms pay the reservation wage ($w = 1$), the source firm has marginal cost $c_{S1} = 1$, and the host firm, due to imperfect transferability of technical skills, has marginal cost $c_{H1} = q$. For the second example, assume N occurred in period 1, and look at period 2 (the cases NT and NN). The host firm would like to get a marginal cost of less than Q, so it will compare $p_H(W/g, Wq/g)$ with $p_H(W,Q)$ and match any source firm wage offer up to the W which makes these two equal; that wage is gQ/q. At this wage the host firm is indifferent between employing a trained worker and an untrained worker. What is the lowest value of q at which the source firm is willing to pay gQ/q to prevent technology transfer? For linear demand, it is $q = 2$. This is because $p_S(1/g,q/g) = p_S(Q/q,Q)$ only when $q = 2$. So when $q > 2$, the source firm wins the wage bidding and the host firm actually pays $w_{H2} = 1$, as shown in Table 1. We now derive the value of w_{S1}, the wage which the source firm pays in period 1 in the case *NN*.

The case which distinguishes the two-period solution from the one-period solution is *NN*. Compare $c_{H2} = Q$ under *NN* with $c_{H2} = q$ under *TN*: the host firm has lower marginal cost if *TN* occurs. In other words, if *N* occurs in period 2, the host firm is better off if *T* has occurred in period 1, since it enters period 2 with a workforce trained in the previous vintage. The fact that this is true affects the outcome in the *NN* case, because it gives the host firm an additional motive to secure *T* in period 1. The host firm is willing to bid more than Q/q because to prevent technology transfer, and hence also its marginal cost c_{S1} (which equals w_{S1} since the unit labor requirement is unity). It also turns out to shift the period-1 switchpoint, so that in the case in which *N* occurs in period 2, technology transfer occurs over a wider range of values of q than in the one-period model.

To see why, we look first at the host firm's choice of the maximum wage it is willing to pay to recruit a source firm worker. The host firm's maximum wage offer satisfies:

$$p_H^{\underline{T}N} + p_H^{T\underline{N}} = p_H^{\underline{N}N} + p_H^{N\underline{N}} \qquad (1)$$

where the first term is the period-1 host firm profit when the two-period outcome is *TN* (the underlined letter tells which period's profits are indicated); the second term is the period-2 host profit when the two-period outcome is *TN*; and so forth. The LHS records the total two-period profit when *N* in period 2 is preceded by *T* in period 1; the RHS records the total profit when *N* in period 2 is preceded by *N* in period 1. Spelling out equation (1) with the relevant marginal costs inserted, we have:

$$p_H^{TN}(W_{H1}, W_{H1}q) + p_H^{TN}(1,q) = p_H^{NN}(W_{H1}, \Theta) + p_H^{NN}\left(\frac{\Theta}{q}, \Theta\right) \qquad \text{(1a)}$$

Recall that in each term, the first argument is the source firm's marginal cost and the second is the host's.[2] Glass and Saggi observe that if c_H/c_S is a constant greater than unity (here $c_{H1}/c_{S1} = q > 1$)[3], then $\frac{¶p_H(w,wq)}{¶w} < 0$, so that as both firms' marginal costs rise proportionately as they make increasing matched wage offers, host firm profit falls. Applying this principle, the second term on the LHS exceeds the second term on the RHS because $Q/q > 1$ by assumption. When $W = 1$ the first term on the LHS is greater than the first term on the RHS. But in the first LHS term $c_{H1}/c_{S1} = q$, so this term declines as W_{H1} rises, while the first term on the RHS rises with W_{H1}. Eventually the host firm's maximal wage offer is reached when the LHS equals the RHS.

Notice that the situation described by this equation is a hypothetical one. In practice, whenever the host firm is willing to match the highest wage the source firm is willing to pay, both firms know this, so the source firm will surrender, recognizing that it cannot prevent technology transfer. Hence the source firm will pay just the reservation wage $w = 1$, whereupon the host firm will do the same. In reality, then, we would have $p_H^{TN}(1,q)$. Nevertheless, Glass and Saggi's procedure is to calculate W_{H1} for the hypothetical case described in equation (1a) in order to find the value W_{H1} that the source firm would have to pay in order to prevent technology transfer.

It is instructive to rearrange equation (1a) as:

$$p_H^{NN}(W_{H1}, \Theta) - p_H^{TN}(W_{H1}, W_{H1}q) = p_H^{TN}(1,q) - p_H^{NN}\left(\frac{\Theta}{q}, \Theta\right) \qquad \text{(1b)}$$

[2] We assume for simplicity, here and throughout, that period-2 profits are not discounted.
[3] In fact, with linear demand we only need $q_1 > 1/2$.

The LHS represents the period-1 sacrifice made by the host firm, paying W_{H1} in order to secure technology transfer and reap the period-2 gain represented by the RHS. Using Cournot analysis in the case of linear demand[4], implying

$$p_H = (1/9b)(a - 2c_H + c_S)^2$$

we can write this as

$$(a - 2\Theta + W_{H1})^2 - (a - 2W_{H1}q + W_{H1})^2 = (a - 2q + 1)^2 - \left(a - 2\Theta + \frac{\Theta}{q}\right)^2 \qquad (2)$$

Solving for W_{H1}, we have

$$W_{H1} = \left(\frac{1}{2(q-1)}\right)\left(\left(a - \frac{\Theta}{q}\right) - \sqrt{\left(a - \frac{\Theta}{q}\right)^2 - 4\left(1 - \frac{1}{q}\right)B}\right) \qquad (3)$$

where $B = \Theta(a - \Theta) + \left(q - \frac{1}{2}\right)\left(\frac{\Theta}{q} - 1\right)\left[a - \left(q - \frac{1}{2}\right)\left(\frac{\Theta}{q} + 1\right)\right]$

where the other root has been dropped because it implies negative output and profit.

Also, we are only interested in real values of W_{H1}. Let us denote by q_A the lowest value of q which is a boundary between real and imaginary W_{H1}. At q_A, equation (3) gives $W_{H1} = \dfrac{a - \Theta/q}{2(q-1)}$. Over any part of the interval $[1, Q]$ over which W_{H1} is real, the host firm will match any source firm wage up to the value of W_{H1} given by equation (3). Elsewhere in the interval, the only upper bound to the host firm's wage offer is a wage which gives it negative profit.

Over what range of q will the source firm choose to match the host firm's wage offer and enforce N in period 1? We now proceed to determine how high a wage the source firm is willing to pay. Again, we approach the question by comparing the source firm's total (both

[4] Glass and Saggi assert that their analysis applies generally to either concave or linear demand. In this paper I

periods) profit under *TN* with its total profit under *NN*. In the source firm's equation the marginal costs are the same as in equation (1b) for the period-2 profits $p_S^{T\underline{N}}$ and $p_S^{N\underline{N}}$, but they differ for the first period. In the $\underline{N}N$ scenario, the source firm pays a wage $W_{H1} + e$, just above the highest wage the host firm is willing to pay, and so ensures that no period-1 technology transfer occurs.

$$p_S^{\underline{T}N}(1,q) + p_S^{T\underline{N}}(1,q) = p_S^{\underline{N}N}(W_{H1},\Theta) + p_S^{N\underline{N}}\left(\frac{\Theta}{q},\Theta\right) \tag{4}$$

The solution to this equation gives us a curve representing the source firm's maximal wage offer as a function of q. In Figure 1, this curve for W_{S1} (the maximal wage that the source firm will pay to continuing employing a source firm worker in period 1) as a function of q is graphed, along with $W_{H1} = \dfrac{a - \Theta/q}{2(q-1)}$, which is the boundary of real W_{H1}, and the W_{H1} curve given by equation (3).

Is the range of values over which *T* occurs in period 1 larger or smaller than in the static game? The intersection of the two curves in Figure 1 occurs at q_1, the source firm's period-1 switchpoint between the *T* and *N* outcomes. Thus equating the $W_{H1}(q)$ obtained from equation (4a) with the host firm's maximal wage offer and solving for q with $\{Q, q, g, a\}$ as parameters gives the switchpoint q_1 below which *T* occurs and above which *N* occurs. This switchpoint must be greater than the switchpoint for the static game, based on the following argument: At the switchpoint for the static game (for linear demand, $q = 2$) the host firm is willing to pay Q/q and no more to secure *T*; hence the source firm is forced to pay Q/q to enforce *N*. And $q = 2$ is the lowest value of q at which the source firm is willing to do this,

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only discuss the case of linear demand.

because at $q = 2$ we have $p_S(1,q) = p_S(Q/q,Q)$. But in period 1, where N is to occur in period 2 (i.e., with $q > 2$), at a hypothetical wage of Q/q equation (1a) becomes:

$$p_H^{\underline{T}N}\left(\frac{\Theta}{q},\Theta\right)+p_H^{T\underline{N}}(1,q)=p_H^{\underline{N}N}\left(\frac{\Theta}{q},\Theta\right)+p_H^{N\underline{N}}\left(\frac{\Theta}{q},\Theta\right) \qquad (5)$$

and this means the host firm is willing to pay a wage higher than Q/q to get T . Is the source firm willing to match such a wage at $q = 2$? No, because its decision is based on equation (4), which becomes:

$$p_S^{\underline{T}N}(1,q)+p_S^{T\underline{N}}(1,q)=p_S^{\underline{N}N}\left(\frac{\Theta}{q},\Theta\right)+p_S^{N\underline{N}}\left(\frac{\Theta}{q},\Theta\right) \qquad (6)$$

and this is an equality because at $q = 2$ these profits are equal, as noted above. Thus at $q = 2$ the source firm is not willing to match the host firm's wage offer, and the switchpoint is therefore higher than in the static game.

To sum up, for some sets of parameter values the solution to the one-period game also solves the two-period game, and the same amount of technology transfer occurs; for example, this is true when $q_2 < 2$ so T occurs in period 2, and for all lines in Table 1 except *NN*. But the one-period solution fails when $q_2 > 2$ so that N occurs in period 2. In that case the source firm will choose to let technology transfer occur for any $q < q_1$, and we have shown that $q_1 > 2$.

4. The three-period and the *n*-period model

We now sketch the extension of the model to three periods and then to n periods. As before, if in periods 2 and 3 T is expected to occur (say, because $q_2 < 2$ and $q_3 < 2$), then the one-period solution applies to period 1. But if N is expected in the last period (period 3), then we apply the two-period solution to period 2 to find its switchpoint q_2. Now suppose that the parameter values lead to the conclusion that *NN* occurs in the last two periods, and further, that they imply that the one-period solution does not apply to period 1. Can we simply apply the two-period solution to period 1? No. The reason is that the benefit to the host firm (or loss to the source firm) of securing *T* extends over the *two* following periods, since having q_1 as a fallback position is still somewhat valuable in period 3, as long as it carries a lower marginal cost than employing untrained workers. Thus both firms will take this into account, and in this instance the three-period solution will differ from the two-period solution: the switchpoint in period 1 (q_1) will be higher than q_2 for this special case, and so in the three-period game, technology transfer will be more likely in period 1 than was true in the two-period game.

The same principle applies to the *n*-period game. Any occurrence of *N* expected at any future point will have an effect backward in time for as long as the parameters imply that *N* occurs. The effect will be qualitatively similar, and where a sequence of *N*'s occurs of length *m* with the last *N* occurring in period *n*, the sequence of switchpoints will obey:

$$q_{n-m} > q_{n-m+1} \ldots > q_n = 2$$

Thus for this sequence of *N*'s to occur, the q_j for $j = n - m, n - m + 1, \ldots n$ have to lie above the monotone sequence of q_j's, which increases moving backwards in time from the last occurrence of *N* in the series.[5]

The result, then, is that technology transfer occurs over a larger set of parametere values, the more periods there are in the game. Thus if the empirical findings reported in

[5] An interesting question is whether the supremum of the sequence of q_{Sj}'s in the case of an infinite sequence of *N*'s (backwards in time) is Q or some smaller number. If it is Q, the implication is that the GS model extended to an infinite number of periods predicts that an intertemporal no-technology-transfer equilibrium will prevail only if movement of workers from the source to the host firm does not raise actually raise host firm productivity.

Harrison (1996) represent a long-term outcome this model is not very good at explaining these results.

5. Conclusion

We seek a model that incorporates some realistic features of the wage bidding between a multinational and a local firm for the services of trained labor, and explains two empirical facts: that FDI sometimes fails to lead to technology transfer to local firms in developing countries, and that multinationals in these countries pay a higher average wage to skilled workers than do locally owned firms. The search was begun with an existing simple model by Glass and Saggi (1999). In their model, technology transfer can fail to occur, but the wage determination process leads to the lack of a wage premium for skilled workers in the case that technology transfer occurs. Making wage determination more realistic by adding a wage counteroffer by the source firm unfortunately makes technology transfer impossible. Moreover, though it does result in skilled workers always receiving a wage premium over unskilled workers, it also results in the host firm paying a higher wage than the source firm, contrary to empirical evidence.

The original model is then extended by adding a second period in which a new and more productive technology is introduced. This increases the range of parameter values over which technology transfer occurs, and extending the model to further periods further expands the region over which T occurs. A model that yields a lack of technology transfer over an extended time period therefore needs to incorporate factors which motivate the source firm to make a higher wage offer to prevent technology transfer. Introducing costly and timeconsuming training has the potential to do this, and such a model is explored in a companion paper.

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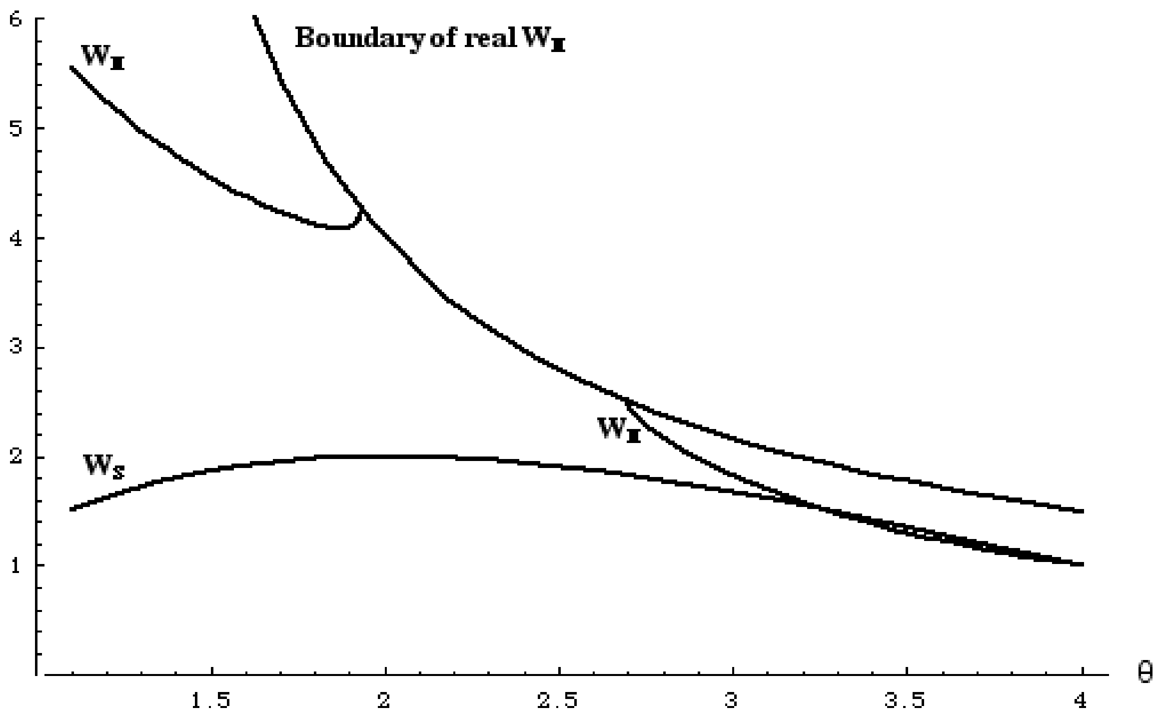

Figure 1. The maximal wage offer curves of the host firm and source firm as *q* varies in period 1 in the two-period game. Here, *a* = 10, *Q* = 4. Technology transfer occurs for *q* < 3.2 or so.